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Investigating the relationship between the perceived thickness of the chocolate pudding in sensory and instrumental analysis

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Abstract

Sensory evaluation of food materials is an important factor to choose and even produce new formulations. Being time consuming, results in being difficult to interpret and the necessity to educate specialists make these methods kind of impractical. In this study, we have made an effort to introduce physical properties as a substitute for sensory evaluations in a semi solid food such as chocolate pudding. Higher reliability, reproducibility and higher pace are among some of the advantages of instrumental measurements. Thus, if sensory evaluation can be predicted based on physical properties solely, besides increasing the inspection pace, they would be available to be used online. The obtained results can also be used in designing new products for special consumers such as the dysphasia patients. The results showed that parameters such as shear viscosity, plastic viscosity, yield stress, extensional viscosity, apparent modulus and adhesive force can be used to design and produce new materials; they make sense beside each other though. In this way, the products which have been designed for the patients with swallowing difficulties should have suitable texture in mouth and also good swallow ease.

Key words: Dessert, Principal Component Analysis, Rheology, Sensory, Texture, Viscosity.

Introduction

The importance of food texture has been highlighted since 1960; the time where Szczesniak presented a new category for texture attributes (Mathmann, *et al*., 2007). He defined texture as the food structure and a way to physiological sense. The mechanical receptors are sensitive to the strain in the food paste and transmit the signals to brain. But at the moment, the aim of studies in this field is identifying the sensory characteristic independent from the sensory evaluations and just with knowing its physical characteristics (Chen, 2009, Mishellany-Dutour, 2006). To achieve this, the usage of a tongue-palate model system has been well designated. Due to mouth anatomy, including lips, teeth, tongue and palate as the organs responsible for speech, mastication and swallowing, the so-called model is limited thus to the fluid flow between the palate and tongue. Considering these two parallel sheets, the flow can be defined in mouth. (Mathmann, *et al*., 2007).

During chewing, the food material changes shape from its initial form to a bulk which is easy to swallow, this soft bulk which is the result of mastication and being mixed with saliva is called bolus. Chewing is the main oral operation for solids and semi-solids and changes the food pieces to particles which are small enough to be mixed with saliva. Thus the result of chewing is a soft bolus which can be swallowed safely (Chen, 2009; Chen & Lolivert, 2009; Funami, 2011; Loret, *et al*., 2011). Strassburg *et al*., (2005) analyse the intra-oral pressures and stress fields according to the concentration of particles randomly distributed in the food suspensionwith the aim to explain the sensation of grittiness. Even though swallowing is a routine action known well to each health individual, its controlling mechanisms and the determining criteria in triggering a swallowing are still little known. There has been no quantifiable parameter to assess the extent of a food being orally processed and its readiness for swallowing. Hutchings and Lillford (1988)

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were probably the first to address this issue by proposing three degrees of an eating process: the degree of food structure, the degree of lubrication, and the time. It was proposed that, before a swallowing is triggered, a critical threshold must be reached for all three factors: a long enough oral processing time, small enough food particles, and a proper oral lubrication. Even though there has been no experimental evidence to support this theory then, some complimentary experiments such as Engelen *et al*. placed emphasis on the particles' dimension, shape and quantity (Engelen *et al*., 2005). From this approach, the research on food brittleness and bolus rheology is being rapidly increased nowadays, because it is the key approach to optimize foods for different purposes e.g. dysphasia patients (Funami, 2011). Though this approach has been tested by many researches, it has mostly been focused on the solids and foods with low fluidity and deformability such as vegetables, nuts or different kinds of meat (Jalabert- Malbus *et al*., 2007; Lucas *et al*., 2002; Mishellani-dutour, 2006; Peyron *et al*., 2004). But viscoelastic gels, which can be used as a base for dysphagia food, have rarely been studied (Chen & Lolivert, 2009). The rheology of semi-solid food, such as gels and jams with special focus on the ease of swallowing and food extensionability, as key factors in triggering a swallowing action has recently been noticed (Ishihara *et al*., 2011a). This attitude is different as a result of using shear viscosity as a prominent rheological property. The viscosity is measured at different shear rates so that we can imitate the passage of food through the oral cavity (Kumagai *et al*., 2009).

Mechanical cohesiveness of the food bolus can be the other prominent rheological parameter to describe the swallow act. It has been reported that mechanical properties of the different food bulk are slightly different for different individual (Prinz & Lucas, 1997). This leads us to predict how fast and easy the food turns into its swallowable form, which is a very important feature for designing food for different uses.

Based on Wikipedia definition, chocolate pudding is a kind of milk based dessert which contains starch, sugar and is chocolate flavored. There are two different kinds of this product, a kind which is set after boiling and contains starch, and a kind which is baked by steam and has a cake-like texture.

To achieve the desirable thickness for this dessert we need hydrocolloids. Two frequently used gums in sweet desserts are guar gum and xanthan gum. Guar gum is a kind of galactomannan and its chemical structure is based on a (1, 4)-linked β-D-mannose backbone and (1, 6)-linked-D-galactose side chains. Its mannose to galactose ratio is around 1.8, due to the different substitution of the galactose, this gums have different solubility in water (Alexander, 1999; Anderson, 1988).

Xanthan is a microbial hetero-polysaccharide and is resulted from the aerobic fermentation of the bacteria *Xanthomonas campestris,* which has a main cellulose chain and on each second chain a side chain of two mannose units exist which have been separated from each other by a glucorunic acid chain (Casas, 2000, Dickinson, 2003).

Kokini & Cussler (1987) used a tongue-palate system to predict the thickness perception in mouth for a food suspension. The shear stress caused by the horizontal and vertical movements of the sheets was measured based on the mechanical information and geometrical properties of the system. In that work, a correlation was made between this data and the apparent relative thickness was calculated. Thus the apparent thickness of every food deducted from the shape of its flow diagram. In another work, Kokini, 1987 also observed that the creamy sense can be predicted through three other factors namely thickness, lubricity and fluidity. These three characteristics were able to explain the differences between the creaminess observed in a group of 16 commercial products with different rheological properties.

In the recent works, the rheological properties of the food bolus have been studied using the polysaccharide gels (Ishihara et al., 2011b). The food bolus has being produced through instrumental chewing, with and without artificial saliva. The gels were inserted in an instrument with a flat plunger. The most common gels used, were gellan (a relatively elastic gel) and a mixture of gellan and psyllium (a relatively plastic gel).

The model bolus is tested as a set of micro gels and gels consisting gel parts with different sizes due to the mechanical chewing (Ishihara *et al.*, 2011a). As a conclusion it can be said that finding suitable weak gels with high affinity to saliva is the key step to design foods for dysphasia patient or any other kind of food with desirable texture.

Chen *et al*. (2011) studied the effect of rheological properties, namely shear and extensional flows of the food gels and their relative bolus was measured at body temperature (37°C). It was seen that the shear viscosity has got a positive correlation with difficulty of swallowing, however the extensional behavior of the food products is better correlated to this factor.

To look for possible relationship between the sensory attributes of the chocolate pudding as a suitable and enriched dessert for the patients with swallowing disorders, and the physical properties of this food product, two commercial gums, xanthan and guar gum, were added in different concentrations to the chocolate pudding, so that the sensory evaluation of the individuals can be investigated beside the physical properties such as extensional and shear viscosity and texture parameters. So, the steady shear rheological properties of the samples containing the two gums were measured and the flow behavior was modeled using different time-independent rheological models. Also to find a good relationship between sensory attribute and rheological features extensional viscosity as a less literature highlighted attribute was also measured. To make sure of the so-called correlation, texture studies were also performed and finally the principle component analysis was done to categorize the features and select the most effective ones.

Material and methods

Chocolate pudding preparation

The ingredients including milk, sugar, wheat flour, vanilla and cocoa powder were purchased from the local market. Due to the literature review which was done before, two selected gums i.e. guar and xanthan were used in three concentrations (0.05, 0.075, and 0.1). First of all, the ingredients were added to milk at room temperature and were mixed till they were dissolved adequately. Then, the mixture was heated to fixed temperature of 75°C that is the approximate temperature at which starch is gelatinized. At this temperature, mixing was continued for 10 more minutes. After that, the pudding was transferred into the special plates with randomized colors in order to the sensory evaluations to be performed. Before carrying out the consequent analysis, the samples were kept for 24 hours at refrigerator (4± 1).To prevent the moisture loss, the sample containers were completely sealed.

Sensory evaluations

In order to do the sensory evaluations, 9 judges from both genders and different age range (6 males and 3 females between 18 to 35 years old) were selected. To screen the panelists at the first training session, two identical samples were presented to 15 persons, in two plates with different numbers and colors, and the sensory panel was performed as the main one. Among them, 9 people with best responses were chosen according to the results of statistical analysis.

After receiving the necessary instructions, 50 ml of pudding samples were presented to panelists in colored plates with codes. Every sample was judged twice by the panelist and in each session three samples along with the control sample were tested. The desired

characteristics were appearance, texture, mouth feel, swallow ease and the time needed for swallow, which were marked on a scale of 1 to 5. One is being the least and 5 the most desirable. To obtain the time needed to swallow, the panelists were asked to give a signal by their hands when they have swallowed the sample and the chronometer was started as soon as they put the sample in their mouth (Chen & Lolivert, 2011).

Instrumental texture analysis

The forward extrusion test was performed using a QTS texture analyzer (CNS Farnell Com, U.K). The pudding sample was placed in an aluminum cylinder container (l=0.1m, r=0.05m). The load cell used was 5 kg and the probe (a round aluminum plate 0.01 m thickness and 0.048m thickness) moved downward with a speed of 1mm/s. For each test, some textural parameters including fracture force, apparent modulus, hardness, cohesiveness, adhesiveness and adhesive force were also determined using QTS software from force-deformation data.

Shear viscosity measurement

To determine the flow behavior of the samples, a Bohlin rotational viscometer (Bohlin Model Visco 88, Bohlin Instruments, UK) equipped with a temperature control system (Julabo, Model F12-MC, Julabo Labortechnik, Germany) was used, and the temperature was set as 37°C±0.1. Appropriate measuring spindle (C14) was used during viscosity measurements according to the viscosity of samples. Each sample was subjected to a programmed shear rate logarithmically increasing from 15to 200 s^{-1} and each measurement was repeated 3 times. After the measurements, flow behavior of samples was described by fitting shear stress (τ)-shear rate ($\dot{\gamma}$) data with four models: Power-law, Herschel-Bulkley, Bingham and Sisko (Steffe, 1996). To select the best model describing time-independent rheological properties of pudding samples, two statistical parameters including RMSE (Root Mean Square Error) and R^2 (coefficient of determination) were determined using Excel (2007). Apparent viscosity of all samples at shear rate of 50 s^{-1} was also calculatedto compare the sensory and rheological data. It should be mentioned that viscosity measurements at 50 s^{-1}, as suggested by Wood (1968), were in reasonable agreement with those derived from panel scoresand it has been reported as an effective oral shear rate (Morris, 1993).

Extensional viscosity measurement

Based on Steffe (1996), for a standard material, in which the ratio between shear and extensional viscosities is small, the extensional viscosity is proportional to entrance pressure drop divided by the apparent wall shear rate in the die:

$$\eta_E = C\frac{\delta P_{en}}{\Gamma} \quad (1)$$

Where, C is a dimensionless constant, which is a function of the system geometry, and does not depend on strain rate or rheological properties of the system. This constant can be calculated using a material with known extensional viscosity in the measuring system. In this study, the silicon oil, which is a Newtonian fluid, was used. The apparent wall shear rate is defined as:

$$\Gamma = \frac{4Q}{\pi R^3} \quad (2)$$

Where, Q and R are volumetric flow rate and orifice radius, respectively. This equation can be used for a zero length die where it is assumed that the entire pressure drop is the entrance loss. The system is illustrated in Fig.3. In this system, a plunger is moving down with the constant velocity (u_z) and forces the material out of an orifice with 90° angel. The entrance pressure loss can be calculated using the force on the plunger and its cross sectional area, as given by eqn.3.

$$\delta P_{en} = \frac{F}{\pi R_b^2} \quad (3)$$

Where, R_b is plunger radius. Assuming the material incompressible, the volumetric flow rate through the orifice is

a function of plunger velocity:

$$Q = u_z \pi R_b^2 \quad (4)$$

Using eqn. 1 and the above definitions, eqn.5 can be estimated:

$$\eta_E = \left(\frac{C}{4\pi}\right)\left(\frac{FR^3}{u_z R_b^4}\right) \quad (5)$$

In this work, as shown in Fig.1 we used a cylindrical barrel with 0.05m radius, 0.1m height and a 10 mm orifice. The temperature of system was fixed at 37°C using a water bath. The measuring of maximum force was done using the QTS texture analyzer (CNS Farnell Com, U.K).The plunger velocity was set as 1 mm/s based on the information which exists in literature to imitate swallowing (Ishihara *et al.*, 2011a).

Principle component analysis (PCA)

The PCA analysis was performed to find out the relationship between different variables existing in this study. This analysis was completed using a SPSS package (IBM SPSS statistics 20).

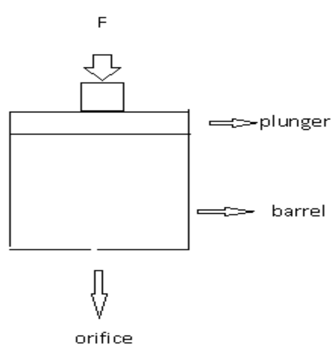


Figure 1.The measuring apparatus of the flow through the orifice is controlled by the plunger

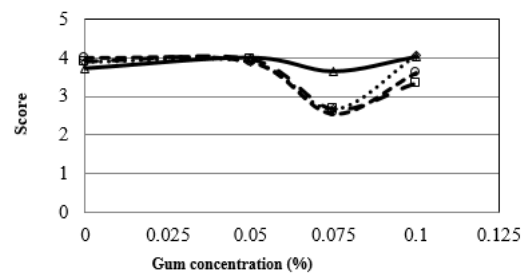
Result and discussion

Sensory attributes

Fig. 2a & b shows the results of the sensory evaluation for samples containing guar and xanthan. It can be seen that the puddings containing guar gum demonstrated a more regular procedure, which is nearly the same for all the parameters. The sample with the highest concentration had the most desirable appearance and texture, and the control sample showed the best mouth feel and highest swallow ease. At 0.075%, a sudden downfall in the desirability of the samples was observed.

The samples containing xanthan showed this trend just for the appearance of the samples and about the other parameters, just opposite of the guar, the sample containing 0.075% xanthan had a relative desirability. This difference may be due to the different thickness caused by these two gums. As xanthan causes a high viscosity at low concentrations, the concentration higher than 0.1, the stiffness of the samples becomes undesirable.

About the mouth feel and swallow ease, due to the data it can be deducted that, the best sample according to the panelists, had an optimum level of thickness. Both the too smooth and too stiff samples were considered undesirable.



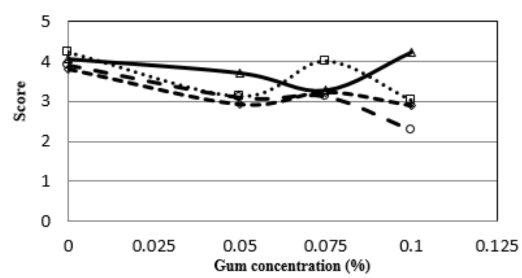


Figure 2.a) Sensory evaluation results obtained for chocolate pudding samples containing guar (Δ, appearance (sdv: 0.81); ◊, texture (sdv: 1.31); ○, mouth feel (sdv: 1.11); □, swallow ease (sdv: 1.08)) b) Figure 3b. Sensory evaluation results obtained for chocolate pudding samples containing xanthan (Δ, appearance (dsv: 0.85); ◊, texture (sdv: 0.91); ○, mouth feel (sdv: 0.80); □, swallow ease (sdv: 0.77))

Textural parameters

The data related to the measured texture parameters for samples containing guar and xanthan are presented in Table 1. As it can be resulted from the data, the control sample, which had the best swallow ease, showed the least adhesive force, least apparent modulus, least hardness and thus

the least stiffness. While the least swallow ease takes place for the sample containing 0.075% guar. Most characteristics of the sample are average and show a significant difference related to its higher and lower concentrations. This behavior is especially significant about apparent modulus, cohesiveness and adhesive force. The so-called data is the same for the sample containing 0.1 % of the xanthan. It can be deducted that about the swallow ease, the sample which has a specific level of thickness, is the most desirable one, i.e. the sample has to be fairly smooth or fairly stiff, and anything between these two is not suitable. This has to be considered while designing food for dysphasia patients (Chen, 2009).

About mouth feel, the sample with the least adhesiveness and the least cohesiveness, i.e. the sample containing 0.05 % guar is the best. Using some additives, it is possible to create a balance between this parameter and swallow ease. About the texture, the

Sample containing 0.1 % guar is evaluated as the best. As it can be seen in Table 1, among the other samples of the same gum, it possesses the highest adhesive force, cohesiveness and apparent modulus. The panelists found the sample which show a resistance to spoon the most suitable, the sample which is fluid-like while spooning is not ideal however.

Shear viscosity

Fig. 3a & b shows how the apparent viscosity of puddings changes with selected gum concentration for guar and xanthan, respectively. As it can be seen, all samples exhibited shear thinning behavior. Thus at the next step, four non-Newtonian rheological models were verified to interpret the steady state flow behavior.

Table 2 shows the values of two statistical parameters (R^2& RSME) determined for validation of the four rheological models used in this study. Based on this, two models i.e. Bingham and Herschel-Bulkley were chosen, due to having the highest R^2 and the least RMSE in all concentrations.

Based on the rheological parameters determined by the Bingham model (Table 3), the sample containing 0.075 % guar, which had the least swallow ease, has the highest plastic viscosity (μ_B).

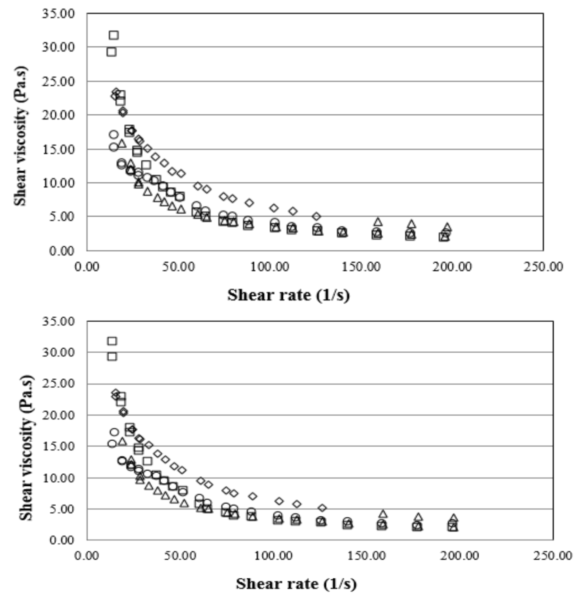


Figure 3. a) Change in apparent shear viscosity of chocolatepuddings containing different concentrations of guar (Δ, 0%; ◊, 0.05%;□, 0.075%; ○, 0.1%) b)Change in apparent shear viscosity of chocolatepuddings containing different concentrations of xanthan (Δ, 0%; ◊, 0.05%;□, 0.075%; ○, 0.1%)

In addition, the control sample, which had the best swallow ease, is the sample with the lowest yield stress (τ_{0B}). The sample with the lowest swallow ease showed an interesting behavior in Herschel-Bulkley model as well and has a higher consistency coefficient (K_{HB}) (Table 4). At the same time, in the Herschel-Bulkley model, it has less yield stress (τ_{0HB}) compared to other samples. It seems that the consumer likes the sample which needs a specific amount of stress to flow and also after being exposed to the stress field of the mouth fluidize faster. The sample containing 0.1% of xanthan has a significant consistency coefficient; however it doesn’t have a good mouth feel, suggesting that the yield stress has a more fundamental role in mouth feel perception. This sample also has a high apparent viscosity (η_{app}) which is almost twice as high as the control sample. The

sample containing 0.075% guar which was not desirable enough has a relatively low apparent viscosity in compare to the sample containing xanthan at the same concent- ration. This also suggests that according to the consumers the before-noted optimum apparent viscosity- neither too stiff nor too smooth samples with enough yield stress to be overcame seem to be the best.

Extensional viscosity

The extensional viscosity data is presented in Table 5. The sample contain-ing 0.075 % guar has the least extensional viscosity and is nearly one third of this amount for the control sample. About this also there is a specific amount for being considered suitable. The extensional viscosity cannot be the only criterion to judge from, when assessing the sample for swallowing. The result may be the manifold phenomena involved in swallowing; the effect of the shear stress caused by the sample which is being processed in mouth is one of them. (Kumagai *et al*., 2009).

PCA analysis

Fig 4 shows the result of PCA analysis for the different sensory factors for samples containing xanthan and guar. As it is seen, for guar the sensory attributes have a near relationship, and this relationship is positive, but about xanthan gum, mouth feel and swallow ease, while having a near relationship are not in agreement with texture and appearance. This suggests the need for a change in formulation to improve the appearance and texture of the pudding through other additives or ingredients such as natural colors and milk powder. The PCA analysis about the swallow ease in the samples containing xanthan at different concentrations (Fig. 5) showed that nearly all the shear viscosity parameters of the used models (Herschel-Bulkley and Bingham) and the extensional viscosity have a near relationship, as it can be seen, the plastic viscosity by being exactly on the other side of the diagram's diameter, seems to have a very strong negative effect on swallow ease, and the same thing was deducted based on the sensory analysis results. The other important factor seems to be the yield stress both in Bingham and Herschel-Bulkley models. This again approves the result of the shear viscosity effect on swallow ease. About the mouth feel, the yield stress in both Bingham and Herschel-Bulkley models is more important, which was also reported in shear viscosity data. Fig. 6 shows the PCA analysis for guar gum. As it can be seen, the relationship between the components for samples containing guar gum is more complicated. For this gum, the important effect of plastic viscosity can be seen here; also the extensional viscosity becomes fairly important, which was seen in the extensional viscosity results as well. About mouth feel similar to the shear viscosity results, the yield stress of the Bingham model introduces itself as an effective factor, though this value in Herschel-Bulkley model does not influence mouth feel as strong as it does in xanthan gum. These results also indicate that there is not just a sole factor determining the sensory acceptability, rather it is a result of multiple factors playing their rules together.

Conclusion

In this work, we tried to obtain physical knowledge on chocolate pudding as a nutritious semi-solid dessert, in order to develop correlation between the sensory evaluation and reliable characteristics such as apparent shear viscosity, plastic viscosity, yield stress, extensional viscosit-y and textural parameters of the product.

The results showed that though each of these parameters can be interpreted due to the sensory evaluation results, none can be the only possible answer, because the swallowing action is the result of many physical phenomena cooperating with each other. However, for specific designing goals, they can be looked at individually or as a collection, e.g. the products specialized for dysphasia patient should have suitable swallow ease beside good mouth feel. Thus the sample with average

extensional viscosity, low yield stress and relatively high consistency coefficient can be the right choice that can be achieved using the right additives. At the same time, these parameters can be good evaluation criterion and can eliminate the need for the difficult and time consuming sensory evaluations. Although the PCA analysis showed the more important factors determining the sensory desirability of the chocolate pudding for different purposes, but the effect of the other factors cannot be underestimated. At the moment, the studies in this area are still very naive and more effort is necessary to study the phenomena involved in mastication and chewing and making them closer to real conditions

Table 1. The results of instrumental texture analysis determined for chocolate puddings containing selected gums

Treatment	Concentration (%)	Apparent modulus (N/s)	Fracture force (N)	Hardness (N)	Cohesiveness (Ns)	Adhesiveness (Ns)	Adhesive force (N)
Control	0	14.43±0.23	9.92±0.60	16.20±0.29	114.56±40	-5.14±0.23	-1.61±0.15
Guar	0.05	15.62±0.22	5.88±0.23	16.15±0.20	47.53±0.31	-2.96±0.21	-1.61±0.10
	0.075	32.48±0.30	4.08±o.11	17.63±0.26	56.88±0.28	-5.31±0.17	-1.73±0.25
	0.1	46.34±0.32	10.34±0.40	49.24±0.23	118.99±0.34	-6.07±0.21	-2.67±0.22
Xanthan	0.05	20.26±0.28	20.27±0.26	20.81±0.25	134.00±0.41	-6.43±0.11	-1.53±0.25
	0.075	22.48±0.13	15.31±0.16	19.50±0.33	122.43±0.33	-7.49±0.26	-1.70±0.15
	0.1	37.96±0.33	33.21±0.22	22.07±0.30	144.79±0.36	-6.97±0.20	-1.97±0.13

Table 2. The values of statistical parameters of four non-Newtonian rheological models determined by fitting of flow curves of chocolate puddings containing Guar

Gum (%)	**0**		**0.05**		**0.075**		**0.1**	
Model	**R^2**	**RMSE**	**R^2**	**RMSE**	**R^2**	**RMSE**	**R^2**	**RMSE**
Power law	0.988	0.396	0.991	0.351	0.973	0.690	0.965	0.702
Herschel-Bulkley	0.994	0.572	0.995	0.476	0.972	0.688	0.980	0.933
Sisko	0.994	0.994	0.996	0.216	0.978	0.432	0.993	0.581
Bingham	0.994	0.266	0.995	0.253	0.972	0.652	0.988	0.365

R^2, coefficient of determination; RSME, Root Mean Square Error

Table 3. The values of statistical parameters of four non-Newtonian rheological models determined by fitting of flow curves of chocolate puddings containing Xantan

Gum (%)	0		0.05		0.075		0.1	
Model	R^2	RMSE	R^2	RMSE	R^2	RMSE	R^2	RMSE
Power law	0.988	0.396	0.966	0.209	0.97	0.69	0.96	0.70
Herschel-Bulkley	0.994	0.572	0.972	0.210	0.995	0.212	0.995	0.212
Sisko	0.994	0.994	0.979	0.211	0.998	0.213	0.996	0.210
Bingham	0.994	0.266	0.934	0.206	0.967	0.209	0.994	0.212

R^2, coefficient of determination; RSME, Root Mean Square Error

Table 4. The parameters of Bingham model (μ_B, Bingham plastic viscosity; τ_{0B}, Bingham yield stress; η_{app}, apparent viscosity at 50 s^{-1}) obtained for chocolate puddings containing selected gums

Treatment	Concentration (%)	μ_B (Pa.s)	τ_{0B} (Pa)	η_{app} (Pa.s)
Control	**0**	**0.844**	**184.41**	**4.532**
Xanthan	0.05	0.730	209.35	4.917
	0.075	0.374	276.06	5.895
	0.1	2.478	445.15	11.381
Guar	0.05	2.218	224.15	6.701
	0.075	3.449	332.49	10.098
	0.1	1.319	455.70	10.433

Table 5. The parameters of Herschel-Bulkley model (K_{HB}, consistency coefficient; τ_{0HB}, yield stress; n_{HB}, flow behaviour index; η_{app}, apparent viscosity at 50 s^{-1}) obtained for chocolate puddings containing selected gums

Gum	Concentration (%)	K_{HB} (Pa.s^n)	τ_{0HB} (Pa)	n_{HB}	η_{app} (Pa.s)
Control	**0**	**44.431**	**205.66**	**0.14**	**5.64**
Xanthan	0.05	40.919	301.01	0.260	8.28
	0.075	14.691	386.66	0.200	8.37
	0.1	51.334	507.89	0.376	14.52
Guar	0.05	19.526	625.41	0.114	13.11
	0.075	63.4	191.41	0.184	6.43
	0.1	45.1	415.42	0.316	11.40

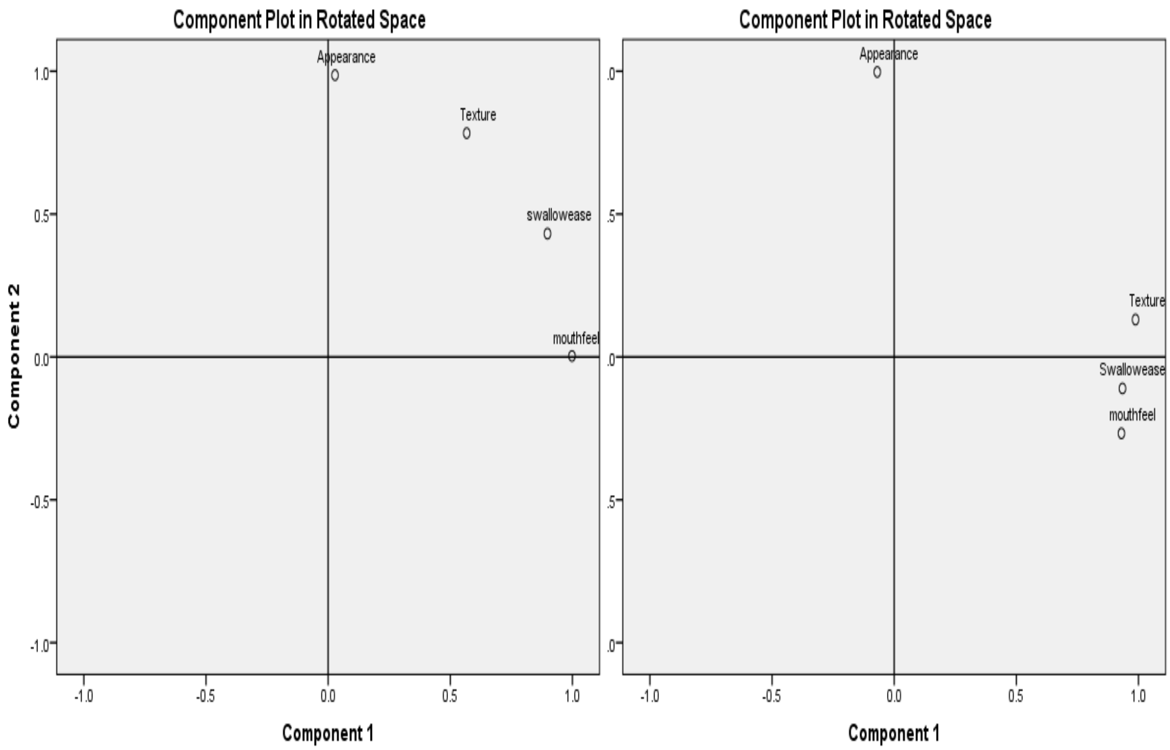


Figure 4. The PCA analysis for the sensory factors of chocolate puddings containing guar (left) and xanthan (right)

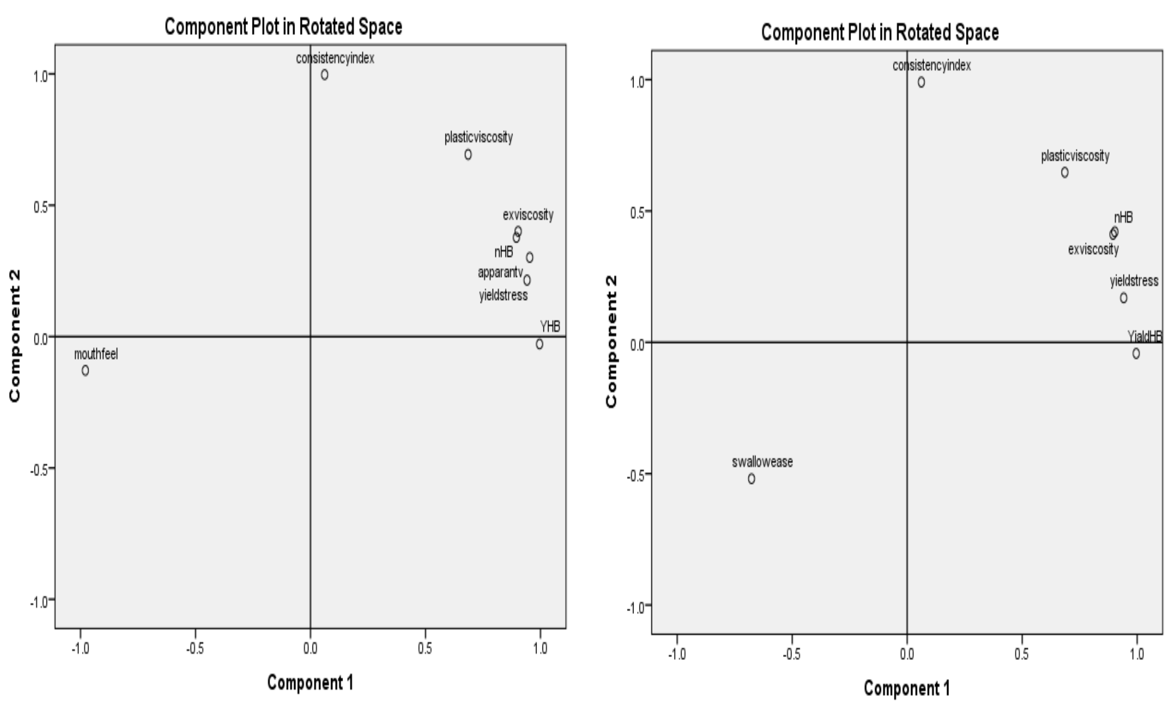


Figure 5. The PCA analysis diagram for xanthan gum on mouth feel (left) and swallow ease (right) with shear viscosity parameters and extensional viscosity

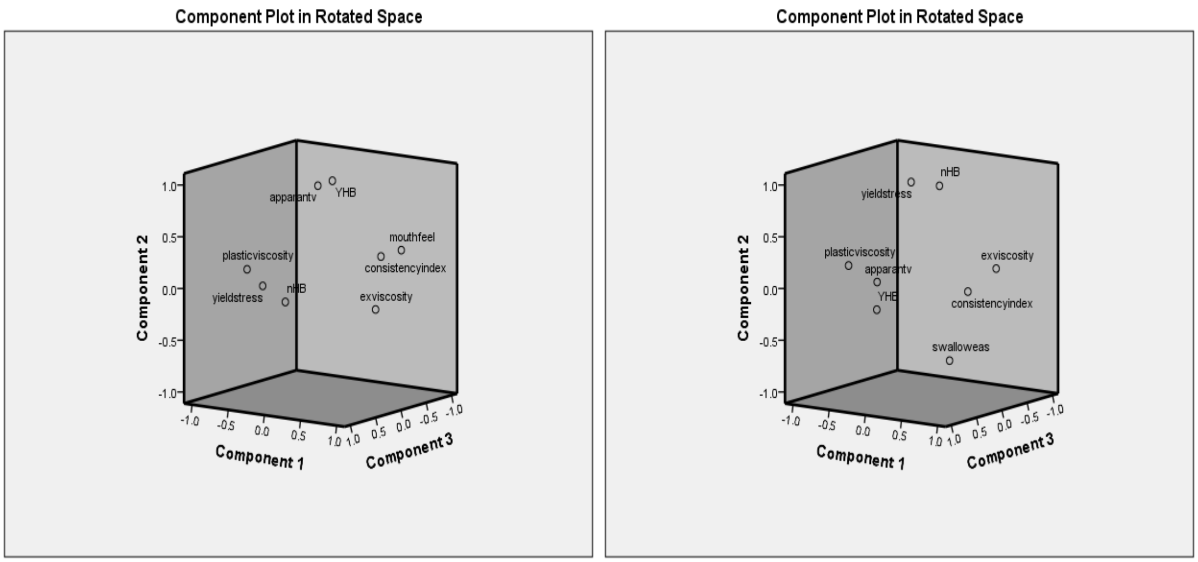


Figure 6. The PCA analysis diagram for guar gum on mouth feel (left) and swallow ease (right) with shear viscosity parameters and extensional viscosity

Table 6. Extensional viscosity of chocolate puddings as a function of gum type and concentration

Treatment	Concentration (%)	Extensional viscosity (Pa.s)
Control	**0**	**922.268±6.0**
Xanthan	0.05	1884.512±2.2
	0.075	1423.379±1.3
	0.1	3087.551±4.0
Guar	0.05	544.807±2.6
	0.075	379.320±1.6
	0.1	961.315±2.2

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بررسی ارتباط بین قوام پودینگ شکلات در ارزیابی های حسی و دستگاهی

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چکیده

ارزیابی حسی مواد غذایی فاکتور مهمی در انتخاب و تولید فرمولاسیون‌های جدید است. وقت‌گیر بودن، سختی تحلیل نتایج و لزوم تربیت متخصص این روش را تقریبا غیرکاربردی می‌کند. در این پژوهش ما تلاش کردیم ویژگی‌های فیزیکی را به‌عنوان جایگرین روش‌های حسی در ارزیابی محصولات نیمه جامد مانند پودینگ شکلاتی معرفی نماییم. اعتبار بالاتر، تکرار پذیری و سرعت بالاتر از جمله مزایای اندازه‌گیری‌های دستگاهی است. بنابر این اگر بتوان ویژگی‌های حسی را تنها بر اساس ویژگی‌های فیزیکی پیش‌بینی نماییم، علاوه بر افزایش سرعت بازرسی می‌توان از آنها به‌صورت برخط نیز بهره جست. همچنین می‌توان از نتایج به‌دست آمده برای طراحی محصولات جدید برای مشتری‌های خاص مانند افراد مبتلا به سختی بلع استفاده کرد. نتایج نشان داد پارامترهایی مانند ویسکوزیته برشی، ویسکوزیته پلاستیک، تنش تسلیم، ویسکوزیته کششی مدول ظاهری و نیروی چسبندگی می‌توانند در طراحی و تولید محصولات جدید مورد استفاده قرار گیرند، هر چند این پارامترها در کنار یکدیگر است که معنی‌دار می‌شوند. در این صورت محصولات تولید شده برای بیماران مبتلا به سختی بلع در کنار سهولت خورده شدن بافت مناسب هم خواهند داشت.

واژه‌های کلیدی: دسر، آنالیز اجزا اصلی، رئولوژی، حسی، بافت، ویسکوزیته

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